Research Paper

An Empirical Study of Building Related Construction and Demolition Waste Management: Waste Handling & Remodeling.

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ABSTRACT

Associated with the development and urbanization of cities, India has been experiencing a rapid increase in Construction and Demolition (C&D) waste. Till now, the generation rate of C&D waste has not been well understood or not explicitly documented in most of the cities, as the country is not following a specific quantification method for the estimation of C&D waste generation. A reliable estimate of construction and demolition waste generation is essential to create awareness about this stream of solid waste among the government bodies in India. However, the required data to estimate construction and demolition waste generation in India are unavailable. This work proposed an approach to estimate construction and demolition waste generation using the combination of the Site Visit (SV) method and Generation Ratio Calculation (GRC) method and demonstrated it by estimating construction and demolition waste generation in study area. The Waste Generation Rate (WGR) of primary materials from both construction and demolition sites in study area were calculated using Regression analysis and the quantification of C&D waste has been done with those WGRs using the selected method. The demolition waste from the study area of flat demolition mainly consists of 97.45% rubble and 1.57% steel. The steel segregated from the concrete was fully reused for civil works after processing. In the reused waste, about 88% was the concrete waste without any processing, used for basement filling, and 10% of the concrete waste was recycled and reused for the production of paver block. As most of the waste obtained from the demolition was reused for different purposes, C&D management in the demolition site can be considered as an eye-opener for the management practices currently followed in other sites of the country. This study and associated methodology may be useful as an expedient, economical, decision-making tool for stakeholders.

1 Introduction

Construction and Demolition (C&D) waste is one of the largest waste flows in the world because of the large-scale construction and demolition activities resulting from the accelerated urbanization and city rebuilding. C&D activities pose a significant threat to the environment and their adverse impacts include waste generation, increased pollution, land deterioration, and resource depletion. The construction and demolition waste constitutes about 10% to 30% of the total solid waste being generated in any society and a significant portion of the C&D waste stream is inert and can be reused or recycled if properly managed. Proper management of C&D waste not only can mitigate the pollution risk but also generate income. Estimation of waste generated from C&D is the most important part of construction waste management. Quantification of construction waste and taking necessary action to address the issue is necessary for the sustainable development of society. Furthermore, it is important to identify causes of C&D waste generation, strategizing waste recycling and disposal, and estimation of the economic value of waste.

The objectives of the present study are framed as follows:

- To estimate the suitable method for quantification of C&D waste in the Indian scenario (under conditions of limited data availability).
- To analyze the composition of C&D waste in study site.
- To study the construction and demolition waste handling practices from different sites in Gujarat.
- To establish the construction and demolition waste generation rates for buildings in Vadodara in the duration of 2021.
- To evaluate the quantity of C&D waste generation using the suitable proposed method.

2 Methodology and Concepts

The whole study is divided in two phases: Phase 1 and Phase 2.

In phase 1, selection of suitable method for the quantification of C&D waste was done. The quantification method for this study was selected among site visit method, generation rate calculation method, lifetime analysis method, classification system accumulation method and variable modeling method. Based on the method selected, proper data was collected from govt. database, site visits and direct and indirect interviews with contractors and site engineers. Flat demolition site was selected as the study area for the quantification of demolition waste as it was the major demolition occurred in Vadodara in the last 2 years. Composition analysis of the demolition waste was done to confirm the primary materials to be taken for the quantification. Also, the demolition waste handling practices followed in the Flat demolition site was identified and calculated the total quantity of each material reused for different purposes.

In phase 2, the composition and handling of the construction waste produced in construction sites of Vadodara were analyzed. Quantification of both construction and demolition waste have been done considering the total area, structural proportion and waste generation rate. The waste generation rate for each primary material from both construction and demolition were evaluated separately using the Regression method and the obtained result will be used for the quantification. The obtained results from composition analysis, handling practices and quantification of the C&D waste from Vadodara were analyzed and compared with that of other states in India.

2.1 Waste Generation Activity

The C&D waste stream is produced throughout the lifecycle of a project, involving construction, usage/maintenance and demolition. During the usage/maintenance stage, waste is rarely generated unless renovation activities are implemented (Su et al., 2012). According to the waste generation amount, primary waste generation activities can be classified in to three: (i) construction of new buildings, (ii) demolition of old buildings, and (iii) civil and infrastructural works.

2.2 Estimation Level

The estimation level is determined by the targeted quantification object and it can be mainly classified into two, project level and regional level.

2.3 Regression Analysis

The main goal of regression analysis is to study the relationship between the waste generated and certain project attributes. Several configurations were tested in order to obtain explainable models, coherent with the behaviour observed at building sites. After calculating each material from both construction and demolition sites separately, waste amount values were reported in the scatter plot to estimate the WGR through regression analysis. The best fitting regression line equation was adopted to estimate the WGR of each material (Islam et al., 2019).

2.4 Waste generation Rate

The key factor in the quantification of C&D waste is the waste generation rate. Estimate the total amount of development activity within the region and multiply it with the waste generation rates determined at the project level to arrive at the regional estimates (Ding and Xiao, 2014). The development activity is quantified in terms of total floor area of the buildings constructed/demolished (Ding and Xiao, 2014). The principle of a WGR technique was adopted in this study. The method that was applied to gather required information and calculate the rate of C&D waste generation utilizing regression analysis and comprised four stages. Several methods are available for estimation of the WGR as mentioned in literature review. The present study adopted hard approaches with the following four steps (Ram and Kalidindi, 2017) considering the flexibility in method and availability of data. The approach that was adopted to collect required data and estimate C&D waste generation consists of four steps as described below.

- **Estimating the total floor area of C&D activity:**
  The room and common walkway are selected as a representation of floor area. The total floor area is calculated by the engineers of site investigation and in some cases calculated from the properly scaled drawing.
- **Estimating the proportion of different types of buildings:**
  Buildings can be classified based on the structural type and use of the building. The amount of construction material differs from the types of buildings. As a simple example – for commercial buildings, more glass is used instead of bricks. In contrast, for residential buildings, the scenario is just reverse.
- **Calculating waste generation rate:**
  Research team deployed into the site and note down the quantity of each C&D waste material from a particular amount of C&D activity. The regression analysis was adopted to derive the WGR similar to the previous research by Islam et al. (2019) and Ram and Kalidindi (2017).
- **Integration of data to get total quantity of waste generation:**

The equation given below has been used to calculate the total quantity of C&D waste generation.

$$Q = \sum_{} \quad {}^{n}\sum \quad m\ Ai * WGRjk$$

$$k=1 \quad j=1$$

where Q is the total quantity of C&D waste generated in a region, Ai is the total amount of C&D activity (unit: m2), WGRjk (unit: kg/m2) refers to the waste generation rate of jth type of waste material from kth type of building, m is the number of primary materials, and n is the number of different types of buildings.

This method is described and given by equation in a simple manner which is based on some measurements of the construction, or demolition activity level in a region (by area of the structure, m2) and the average waste generation per building area (kg/m2) to determine the waste generation.

$$W = CW + DW = CA * Gc + DA * Gd$$

where W is the total weight of building-related C&D waste generated during one year (kg/year), CW and DW are the construction weight and demolition waste per year respectively, (kg/year); CA is the area of buildings constructed or innovated and DA is the area of buildings demolished per year (m2/year); Gc and Gd are the average waste generation per building area during construction and demolition activity (kg/m2), respectively.

2.5 Site Visit (SV) Method

This methodology requires investigators to visit the construction or demolition sites for a realistic survey. There are two different approaches for this method, direct and indirect approaches, which can be utilized to collect C&D waste generation data.

- **Direct Measurement:** Direct measurement requires to weigh the waste produced or to measure its volume on site. Before implementing direct measurement, some assumptions have to be made. The assumption should made depending on how C&D waste was stockpiled, gathered, scattered or stacked. For stockpiled waste, a rectangular based pyramid and for gathered waste, the layout shape assumed would be cuboid. After obtaining the volumes of the stockpiled and gathered C&D waste, the mass was derived by using waste volume times corresponding density. For scattered and stacked waste with similar size (e.g., bricks, roof tiles), three samples were randomly chosen from the total. The average weight of the selected samples was calculated and assumed to be uniform. Thus, the total weight could be estimated by using the average weight multiplied by the number of samples (Wu et al., 2014).
- **Indirect measurement:** As direct measurement requires a substantial amount of time and labour; indirect measurement is more frequently used for practical estimation. For example, the employed truck load records to estimate the volume of C&D waste generated on site. The investigators recorded the number of trucks for waste collecting, together with the container's volume of each. Based on this information, the total waste volume at a project level was derived. For the purpose of indirect quantification at a regional level, obtained truck load records from landfills.

  Besides the above-mentioned measurements, interviews with contractors could be further conducted for a verification purpose. This is because on-site professionals often possess relevant background and can give some insights for adjusting the waste generation information.

3 Demolition Waste Composition

Due to redevelopment of study area, demolition of luxury apartments with a carpet area of 2434.05 square meter in Vadodara was done. The demolition of these buildings was conducted on 11th and 12th of June 2021. The manual demolition and concrete swing method was used to demolish those buildings without affecting the nearby buildings.

It was inferred that the demolition waste from the study site mainly consists of rubble a combination of concrete and brick, steel reinforcements, wood and ceramics. Rubble and steel altogether contributed to more than 98% of total waste obtained from those sites whereas the wood and ceramic waste were in a small quantity. In this study, primary materials such as rubble and reinforcement steel are only considering for estimation as they are the major waste materials. The total quantity and percentage constituted by each material are expressed in below Table and Fig.

Material	**Quantity (T)**	**Percentage (%)**
Rubble	2117	97.45
Steel	34.22	1.57
Wood	15.21	0.70
Ceramic	6.08	0.28

4 Demolition of Waste Handling

The demolition of the buildings, Prior to demolition, walls, windows, doors and iron frames of the building had been removed and only the pillars and beams were remaining at the time of demolition. It has been ensured that there are no hazardous objects. About 342.28 tons of concrete debris has been removed.

Total quantity of reused waste for different purposes

Waste	Purpose of remodeling	Quantity (T)
Rubble	Water proofing and basement filling	500
Recycled concrete	Production of paving tiles	25
Concrete	Sold to local dwellers	250
Steel	Civil works	8

Based on the results of the selection of suitable quantification method, it can be inferred that the combination of both site visit method and GRC method gives the most appropriate estimate of the C&D waste generated and thus could be the choice for the quantification method in limited data availability. In the site visit method direct measurement approach and in the generation rate calculation method area- based approach is taken. This is since the direct measurement is less time-consuming compared to the indirect approach and the data regarding the area of the building is more accessible than demographic and financial data. The composition of the demolition waste obtained from study flat demolition mainly constituted by about 97.45% of rubble and 1.57% of steel. From the handling practices followed in the demolition site, it can be inferred that about 88% of unprocessed concrete waste was reused and 10% of concrete waste was recycled and reused. Also, the steel segregated from the concrete was fully reused for civil works.

5 Remodeling of Demolition Waste

People in today's world are consuming an enormous amount of raw materials. Because of this, natural resources are being quickly depleted. With the growth in the population, comes an increase of waste generated by the increasing demand for new highways, commercial buildings, housing developments, and infrastructure projects, which results in a tremendous amount of waste ending up in landfills yearly. With consumer and economic growth there will always be natural resources not only depleting eventually disappear. Awomeso et al. (2010), stated that current environmental concerns have forced developed and developing countries to reduce pollution for sustainable growth, and highlighted the use of effective waste disposal techniques that are suitable for environmental protection.

This thesis will provide foundations for which materials that should be sorted and recycled, as well as how large amounts of wastes that need to be sorted in order for the construction site to conduct profitable business at the sorting site. The profitability of the sorting site scenario will be studied in order to determine the potentials of leasing a sorting site.

5.1 ECONOMIC VALUES C & D WASTE RECYCLING

According to the survey Throughout the building demolition process, we found that electrical wire, other electrical elements, wooden windows and doors were recovered either purpose of reuse or wholesaled in secondary markets. Even the small length of steel enclosed in concrete (after the demolition of structure) is retrieved using gas cutters and sold to steel scrap dealers. Therefore, the wood or steel-related materials used as a waste in a landfill or any other dumpsites are often negligible.

5.2 RUBBLE REUSE

About the project, the initial plan was erecting a building in reused purpose. In general, from the investor's view, this reused design will save more money and be more environment-friendly. But it still need to be considered from a global perspective. The research paper here will focus on this real case.

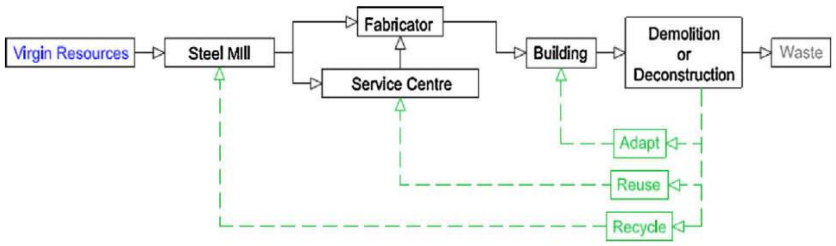
RUBBLE contains Concrete and broken pieces of Red Brick, In that Red Brick which is used for water proofing at construction sites and Concrete which is used for Basement filling and Road Filling at High-rise Building.

5.3 STEEL RECYCLING / REUSE

Recycling/Reuse is the method about reducing the consumption of fresh raw materials by converting useless materials into reusable items. Further reducing the energy usage and greenhouse gas emissions. Sometimes, it will abate the water pollution and relieve the pressure of landfilling.

Steel is a material which has unique capacity of without loss of properties or performance when it is melt. That means however many times changes the shape of steel, it will be same property. About the steel structure in the modern world, due to its widespread use, it is necessary to consider the influence to the environment or society. For instance, about the manufacture industry, the average household appliance contains about 65% steel (Ferrous Processing Trading, 2012). In order to produce steel, it needs to melt the iron ore which is mined from the ground in furnaces where remove the impurities and add the carbon. In this process, there is much CO2 generated. However, recycled steel is just melt or sometimes mixed with iron, then pour into new moulds. It will more save energy and reduce the gas emission. Moreover, the key point is about steel scrap, it can be sourced from different components, construction, manufacture industry or household. Anyway, recycled steel already plays

the important part in sustainable design worldwide.



5.4 CONCRETE RECYCLING

The process of manufacturing is simple and standardized. Cement concrete is a mixture of cement, sand and waste concrete in correct proportions. The items are mixed in water and churned thoroughly in a concrete mixture. The process involves proportioning, Mixing, Compacting, Curing & Drying. A concrete mix of 1:2:4 :: cement: sand: waste concrete by volume are used for making paving blocks.

All the items of raw material are placed in the concrete mixer and water added. The mixer is then rotated for 15-20 minutes. The mixed material is then discharged on to the moulds. Care is taken that the mixture does not dry. Vibrators are employed during the process of pouring the mix so as to ensure that it sets well and is compact there is no porosity. After compacting the blocks are demoulded and allowed to dry for 24 hours away from direct sun. The blocks thus hardened are cured with water to permit moisturisation or settling of cement for next 20 days. The water in the curing tanks is generally changed every 3 days. After being cured the blocks are allowed to dry in shade so that initial shrinkage of the blocks is complete before they are used. This generally takes 15 days.

6 Conclusion

These studies conclude that the use of recycled materials has positive impact through different aspects. This include the benefits in enhancing sustainability of the construction industry while reducing cost, providing solutions to environmental pollution and reducing the need for natural resources. Also, the selection of suitable quantification method gives the most accurate estimation of the C&D waste generated which will helpful to identify the quantity of materials to be recycled. The use of recycled materials reduces dependency on raw materials. Hence, more better awareness and research are needed to encourage the use of waste and recycled materials in the construction engineering.

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